METHOD AND SYSTEM FOR ESTIMATING INPUT POWER IN A CABLE MODEM NETWORK

TECHNICAL FIELD

The present invention relates to cable modem networks, and more particularly to input power estimation methods that compensate for variations in tuner gain characteristics.

BACKGROUND ART

Digital modems are increasingly being used by consumers as cable modem network service providers obtain additional subscribers. Cable modem devices designed for the mass-market are designed to be affordable to as many consumers as possible. However, low-cost, high production devices manufactured for the mass consumer market often exhibit variations and irregularities in their operating characteristics, such as gain non-linearities, frequency ripple and temperature effects. These variations make it difficult to measure the radio frequency (RF) input power to the cable modem accurately.

Currently known calibration solutions do not address variations in the tuner gain and intermediate frequency (IF) amplifier gain in the tuner of the cable modem as the frequency and power level of the input signal changes. Further, any calibration method that applies the same parameters globally to all cable modem devices do not consider the fact that individual devices may exhibit slightly different operating characteristics and may have different irregularities. These variations may adversely affect the cable

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modem's performance if not adequately addressed via an accurate input RF power determination.

Although it is theoretically possible to use the cable modem to calculate data that will compensate for variations in tuner gain characteristics, this would require incorporating additional calculation circuitry into the cable modem, increasing the cable modem's complexity and generating a device that is likely to be too expensive for the mass consumer market.

There is a need for a simple method and system to correct for variations and irregularities that are commonly encountered in low-cost, high volume cable modems when estimating input power to the cable modem.

SUMMARY OF THE INVENTION

Accordingly, the present invention is directed to a method for estimating input power to a cable modem device having a tuner and a modem. The method includes generating a look-up table that contains look-up values used to compute an estimated input power to the modem's receiver. The look-up table is stored in the modem for reference. The method includes inputting a plurality of calibration signals having known input frequencies and known input power levels into the device's receiver, recording a calibration point corresponding to each of said plurality of signals in a calibration matrix, and connecting the calibration points in said calibration matrix to generate the look-up table values.

A cable modem device according to the claimed invention has the look-up table stored in the modem, preferably as 8-bit data. During modem operation, the modem checks the frequency and amplitude of an input signal received by the modem's receiver, checks the look-up table for the look-up value corresponding to the frequency and amplitude, and uses the look-up value to determine an estimated input power. Because the look-up table values are derived from the cable modem device's actual operating characteristics, the input power estimate will reflect any variations or irregularities in the specific device being used.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a representative block diagram illustrating an automatic gain control loop that is used in conjunction with the inventive method;

Figure 2 is a flowchart illustrating one embodiment of the inventive method;

Figure 3a and 3b illustrate an example of generating amplitude points in a look-up table from calibration data;

Figures 4a and 4b illustrate an example of generating frequency points in a look-up table from calibration data;

Figure 5 is a graphical representation of calibration data according to the present invention; and

Figure 6 is a graphical representation of a look-up table according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 is a block diagram representing an automatic gain control (AGC) circuit that is used to generate information to be used for computing input RF power. The AGC circuit 100 is found in the integrated circuit of known digital modems. The AGC circuit 100 includes a power detector 102, a loop filter having gain G(s) 104, and a variable gain device 106, such as a voltage variable amplifier, as well as an adder/subtractor 108 located at input of the filter 104. The AGC circuit 100 is used to adjust the gains of the receiver and intermediate frequency (IF) stages of the tuner in the cable modem to maintain a constant receiver power output. As can be seen in the Figure, the AGC circuit 100 has a closed loop, negative feedback control system configuration, which ensures that the power output of the receiver remains constant.

The relationship between the power out of the receiver of the AGC circuit 100, P_{demod}(dBm) and the input power P_{input}(dBm) can be generally defined as follows:

$$P_{Demod}\,(dBm) = P_{INPUT}\,(dBm) + G_{Receiver}(dB) \qquad (1)$$

If a voltage variable amplifier is used as the variable gain device 106, the expression for the receiver output power can be as follows:

$$P_{Demod}(dBm) = P_{INPUT}(dBm) + V_{AGC}(V/dB) \bullet K_{VVA}\,(dB/Volt) + G_{Receiver}\,(dB) \qquad (2)$$

One specific embodiment, to be used in a digital AGC circuit implementation, is to use digital integrators for accumulating the AGC error signals. The accumulated value of the AGC's integrator register is proportional to the voltage applied to the voltage variable gain device 106 once the loop has reached equilibrium, as indicated by the following expression:

$$V_{AGC}(V/dB) \propto \Psi_{IntAccumValue}(bits) \bullet K_{\Sigma\Delta}(Volts/Bits) \qquad (3)$$

Combining the information in Equations 2 and 3 results in the following expression:

$$P_{Demod}(dBm) = P_{INPUT}(dBm) + \Psi_{IntAccumValue}(bits) \bullet K_{\Sigma\Delta}(Volts/Bits) \bullet K_{VVA}(dB/Volt) + G_{Receiver}(dB) \qquad (4)$$

As can be seen in Equation 4, the input power P_{input}(dBm) of the receiver can be obtained for any given accumulated value of the AGC integrator Ψ_{acc}.

The specific manner in which the accumulated value in the AGC integrator is used to compute the receiver's input power will be explained with reference to Figure 2. Figure 2 is a flowchart that illustrates one embodiment of the inventive method 200. As noted above, the inventive method uses the AGC integrator's accumulated value and estimates the input RF power using an algorithm and look-up table. The look-up table itself is preferably generated during a production phase, after the digital modem and tuner

in the cable modem device have already been manufactured and connected together. During the production phase, a selected number of sample signals having a known power level and frequency are applied to the tuner input at step 202. Each sample signal will act as a sample point for generating a calibration matrix corresponding with that specific cable modem device. Preferably, the sample points include multiple power levels over the same frequency as well as multiple frequencies for the same power level. Of course, if greater accuracy is desired, more sample points can be taken, but doing so will increase the time and expense required for calibration.

Next, the tuner in the cable modem device tunes to each sample signal at step 204 and the AGC loop adjusts the gain of the tuner at step 206 for each signal. For each sample point, the input power Pin, input frequency Fin, and the AGC integrator accumulated value Ψ_{acc} are recorded at step 208. For explanatory purposes, the term "Na" refers to amplitude points in the matrix (with "Na_cal" referring to amplitude points obtained during calibration) and the term "Nf" refers to frequency points (with "Nf_cal" referring to frequency points used during calibration). The calibration points are preferably taken over a large frequency and amplitude range to ensure that the sample points reflect the device's operating characteristics. For example, the inventive method may obtain nine amplitude samples (Na_cal = 9) over 27 dB and ten calibration frequencies (Nf_cal=10) over 764 MHz.

After the calibration data has been obtained and recorded, the inventive method generates a look-up table corresponding to the specific cable modem device at step 210 from the calibration data. Examples of how data in the look-up table is generated are

shown in Figures 3a and 3b (amplitude) and Figures 4a and 4b (frequency). The objective of the look-up table is to provide a look-up value for each channel frequency and amplitude value that may be encountered by the cable modem. The specific amount of data in the look-up table can vary depend on the desired resolution. For example, using the example above, if the desired resolution includes a data point every 1 dB of amplitude and every 6 MHz of frequency, the final look-up table will be a matrix having dimensions Na = 31 points by Nf = 134 points.

To calculate the values for the look-up table from the calibration points, the method includes interpolating between the AGC integrator accumulated Ψ_{acc} for selected amplitude points at a selected frequency during step 210. An example is illustrated in Figures 3a and 3b. The interpolation itself can be conducted using a first or second order equation to fit a curve along the calibration data points to reduce RMS errors. Other interpolation and calibration techniques for linking the calibration points include using an audio tone to reduce the calibration errors caused by modulated signal fluctuations. For multi-band receivers, the inventive method may localize the calibration slope to reduce errors even further. Also, the calibration data can be fitted to known voltage variable amplifier curves to reduce the number of calibration points needed to obtain values for the components' RF tuner gains and IF gain amplifiers. Similarly, additional frequency points can be obtained via interpolation and extrapolation, as shown in Figures 4a and 4b, and stored in the look-up table.

After all of the desired points have been generated from interpolating and extrapolating the calibration data, the resulting look-up table preferably contains one

AGC integrator accumulator value data point for each amplitude and frequency value in the tuner's operating range. When a user wishes to measure the input RF power to the modem's receiver, the AGC integrator accumulator value Ψ_{acc} corresponding to the tuner's frequency is read from the look-up table and used to estimate the input power from Equation 4 above. Because the AGC integrator accumulator value is calculated from a value obtained via the modem's actual operating characteristics, the values in the look-up table will reflect and compensate for any variations in the particular device's characteristics, such as gain non-linearity, frequency ripple, or temperature effects, in the input power calculation.

Figures 5 and 6 are three-dimensional graphical representations of the data generated and used by the inventive method. Figure 5 is an example of a calibration table for a specific cable modem, while Figure 6 is an example of a look-up table that is stored in the cable modem. As can be seen in the Figures, Figure 6 provides a finer, more detailed representation of the plot shown in Figure 5, which primarily acts as a framework for the look-up table. When the user wishes to measure the input RF power to the receiver, the AGC integrator accumulator value Ψ_{acc} corresponding to the tuner's frequency and amplitude is read from the look-up table, such as the one shown in Figure 5, and is used to calculate an estimated input RF power value as explained above. If desired, the dynamic range of the look-up table can be rescaled to accommodate a greater range frequency and/or amplitude values by setting maximum and minimum values for the look-up table.

To save digital memory, the look-up table values are preferably normalized to 8-bits to conserve memory space. The maximum and minimum values can be used to scale the stored 8-bit values to their actual AGC integrator accumulator values Ψ_{acc}.

As a result, the inventive system does not require any calculations to be conducted in the digital modem itself. Instead, the invention uses AGC accumulator register values in a digital demodulator to estimate input RF power using a simple algorithm and a look-up table, using external test equipment to generate the look-up table data stored in the modem. The data in the look-up table is preferably generated externally by interpolating and/or extrapolating points from sparse calibration data and stored in the modem using a compact format (e.g., 8-bit data). During operation, the modem simply references the data corresponding to the input frequency and amplitude in the look-up table to obtain an associated AGC integrator accumulator value. The accumulator value is then used to calculate the input RF power of the receiver. Because the AGC integrator accumulator values in the look-up table are interpolated from the actual, device-specific operating characteristics of the tuner in the cable modem device, the inventive method The inventive system therefore can compensate for gain non-linearity, frequency ripple and temperature effects often found in low-cost RF tuners by including data corresponding to these effects in the look-up table, without requiring an excessive number of calibration points to generate the look-up table data.

It should be understood that various alternatives to the embodiments of the invention described herein may be employed in practicing the invention. It is intended

that the following claims define the scope of the invention and that the method and apparatus within the scope of these claims and their equivalents be covered thereby.